Available online at www.sciencedirect.com
ScienceDirect
Procedia Earth and Planetary Science 1 (2009) 1191–1197
Procedia Earth and Planetary Science
www.elsevier.com/locate/procedia

The 6th International Conference on Mining Science & Technology

Analysis of urban landscape pattern change in Yanzhou city based on TM/ETM+ images

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Abstract

To provide a scientific basis for ecological construction of urban landscape, we take Yanzhou for an example to analyze the urban landscape pattern change. The images of the multi-temporal Landsat TM/ETM+ data in 1998 and 2002 are used to select the best band combinations to interpret images based on the correlation coefficient of bands and Optimum Index Factor (OIF). Then we classify the images using Maximum Likelihood Classifier (MLC) and Support Vector Machines (SVM) classifier. The results of SVM are used for analyzing the urban landscape pattern change in Yanzhou city to obtain its characteristics because it has higher classification precision. The experiment shows a rich diversity, a low dominance of landscape and the common development of landscapes. In the development process of urban and mining area in Yanzhou city, the balanceable development of protecting the objects style is paid more attention to and the ecological environment type keeps in good condition on the whole.

Keywords: mining area; Yanzhou; landsat TM/ETM+ data; classification; landscape pattern

1. Introduction

Urban landscape ecology opens a new idea for understanding and solving the problems of comtemporary urban through the research of human activity center in a smaller scale[1]. With the expansion of landscape ecology, it has been a new thingking method to study the urban ecology. To synthetically and multi-level analyze the spatial structure of urban landscape, remote sensing is widely used[2]. Landscape pattern including different sizes and shapes of spatial landscape category, affects the ecological development and then leads to the change of landscape function. Through the analysis of these landscape pattern, the mechanism and principle of the change of landscape spatial structure can be studied to find the continuous or remarkable change of landscape spatial structure and its effects on landscape pattern[3].

Yanzhou is an important national base of coal resources, which locates in the interchange of Xinshi and Beijing-Shanghai railways[4]. So it is of significance to enhance the research of urban landscape pattern change for regional sustainable development in Yanzhou city. Chen J X analyzed the quality of atmospheric environment of Yanzhou

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doi:10.1016/j.proeps.2009.09.183

mining area[5]. Li T J evaluated an environmental quality of Yanzhou mining area and gave some applicable strategies[6]. Wu X H presented the state of the environment of Yanzhou mining area and gave the corresponding countermeasures[7]. We apply the methods of landscape ecology principle and landscape spatial pattern analysis by selecting the Landsat TM/ETM+ satellite images to study the urban landscape spatial pattern of Yanzhou from both category scale and landscape scale so that the characteristics and trend of urban landscape pattern change can be revealed. Finally, a scientific basis can be given for ecological construction of urban landscape, intensified utilization of regional land and sustainable development of economy and society in Yanzhou.

2. Research methods

2.1. Technical scheme

The analysis of landscape pattern based on TM/ETM+ includes four steps: (1) Pretreatment of remote sensing data including radiometric correction, geometric correction and image registration; (2) False color composite to interprete the images by selecting bands; (3) The terrain classification of remote sensing images by manual interpretation and automatic classification; (4) The analysis of urban spatial pattern change of Yanzhou from both category scale and landscape scale.

2.2. Data preprocessing

TM/ETM+ image data recorded on May 18, 1998 and May 31, 2002 were selected. After the radiation correction, image registration is conducted through image to image mode. The control points were selected in the cross-roads, the corner points and easily identifiable edges. These control points covered the entire study area with the uniform distribution. The required precision of registration was controlled in the 0.5 pixel of the same points in both images. After that, the remote sensing data were obtained according to the vector layer. False color image (May 31, 2002 ETM+ image (7, 4, 1)) is shown in Fig. 1.

Fig. 1. False color image of Yanzhou city

2.3. Best band combinations

Optimum Index Factor (OIF) is put forward by professor Markowitz of United States, the mathematical formula is given by

$$OIF = \sum_{i=1}^{3} \sigma_i \Big/ \sum_{j=1}^{3} \left| R_{i,j} \right| \tag{1}$$

Where σ_i is the standard deviation of the first band i; $R_{i,j}$ the correlation coefficient of i, j band.

According to the OIF and the correlations of bands, the band combination of TM1, TM4, TM7 from TM image in 1998 and the band combination of TM1, TM4, TM7 from ETM+ image in 2002 are the best band combinations. Through massively repeated experiments, if the bands of TM7, TM4, TM1 are given red, green and blue, respectively, the synthesized image contains clearly rich information and is easy to interpret.

2.4. Classification method

Based on the remote sensing image interpretation and the specific circumstances of the study area, the land cover of Yanzhou is classified into 6 types to analyze the urban landscape pattern: cropland, woodland, garden land, water, building area, and bare land. The two groups of training samples in the experimental area are chosen according to the land-use map of Yanzhou (1: 50 000). The first group of training samples are used for MLC and SVM classifier and the second ones used for testing the precision of two classifiers. To enhance the adaptability of two classifiers, some samples in the same ground object are selected with certain distance and there are no overlapping parts between the area of training samples and testing samples.

2.5. Classification accuracy assessment

In the circumstances of software ENVI4.3, the training samples are classified by the MLC and SVM classifier. The testing samples are used for the establishment of the confusion matrix to assess the classification accuracy of two classifiers. The results of two periods images by the SVM classifier are shown in Fig.2 and the classification accuracy of both classifiers are shown in Table 1.

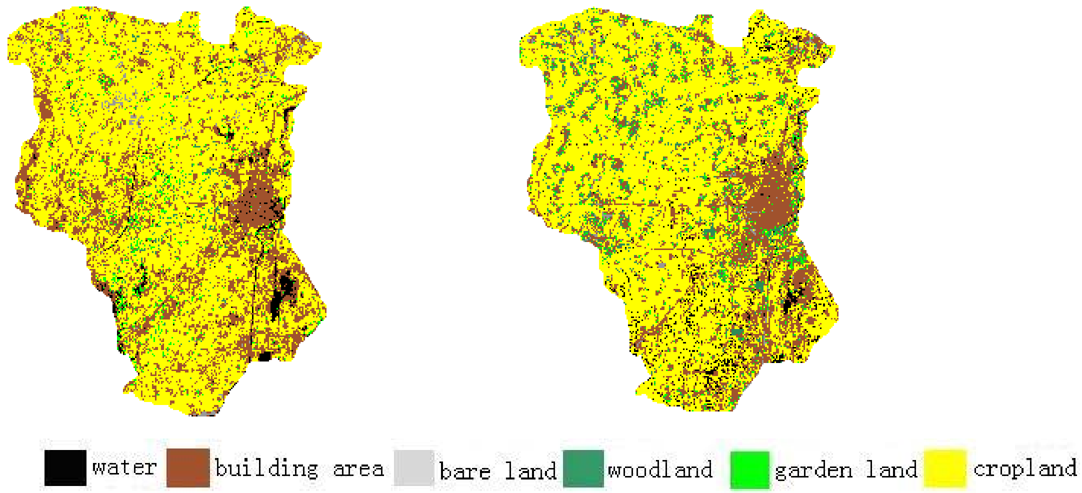

Fig. 2. Classification results by SVM in 1998 and 2002 (a) SVM-1998; (b) SVM-2002

Table 1. Classification accuracy of MLC and SVM

Method	1998		2002	
	Kappa	Overall Acc	Kappa	Overall Acc
SVM	0.8566	88.2832%	0.8906	90.0119%
MLC	0.8270	87.2493%	0.8828	89.1640%

The results of Table 1 show that the SVM classifier has the higher classification accuracy than the MLC, so we use the results of the SVM classifier to analyze the urban landscape pattern change in Yanzhou city.

2.6. Classification results analysis

Land cover classification areas of Yanzhou city using SVM classifier in 1998 and in 2002 is given in Table 2, which compares with the Land-use structure change from Land statistical comprehensive data of Jining (from 1990 to 2003) given in Table 3.

Table 2. Land cover areas by SVM classifier in Yanzhou city (hm^2)

Year	Total area	Cropland	Building area	Wood land	Garden land	Water	Bare land
1998	66958.57	45657.54	16403.47	1019.11	1668.09	1563.39	646.97
2002	66958.57	42001.96	14937.27	3602.81	2432.27	1998.50	1985.33

Table 3. Land use structure change of Yanzhou city (hm^2)

Year	Total area	Cropland	Building area	Wood land	Garden land	Water	Bare land
1998	65111.80	44121.00	15532.07	847.40	1301.53	2755.93	553.87
2002	65111.81	41501.29	14962.95	2093.51	1631.01	2833.77	2089.28

It can be seen from Table 2, land cover has changed in Yanzhou city from 1998 to 2002. Except cropland and building areas, all other kinds of lands have increased. Woodland has a greater increase than garden land, water has a bit increase, and bare land has a greatest increase which is almost two times than before. When compared to the land statistical comprehensive data (Table 3), the statistical precision of cropland and building area are more than 96% and 94%, respectively. The statistical precision of bare land is less than cropland and building area, above 85%. Based on comparing with the areas, the classification results of TM data are not always consistent. The woodland and garden lands are more than the statistical data, but the water is less than the statistical data.

Two periods of remote sensing images show that parts of the rivers in Yanzhou appear droughty and have a increasingly serious trend. These droughts make the mixed pixels of water in images increase to affect the automatic classification of water. Therefore, the water areas are less than the practical areas and the areas of woodland and garden land are more than practical areas. Although the mixed pixels affect the classification of water, the whole classification results are consistent with the practical data and satisfied the analysis requirement of urban landscape pattern change.

3. Landscape pattern analysis

Landscape pattern index refers to the characteristics of highly concentrating the information of landscape pattern, reflecting their structural composition and spatial configuration[8]. These characteristics are able to effectively reflect the effects of human activities on landscape elements in the process of urbanization and provide a quantitative basis for scientifically measuring the rationality of urban structure[9]. Landscape spatial pattern analysis is a method to study the relationship between the composition characteristics of landscape structure and its spatial configuration. In the landscape pattern change analysis, landscape pattern index is a most used method to quantitatively describe the landscape pattern combining the spatial characteristics and time course. We use a landscape pattern analysis software, Fragstats, to calculate various ecological landscape indices to research the urban landscape pattern change. These indices includes landscape diversity index, landscape shape index, patch density, the average fragmentation index, plaque rich and landscape dominance index[10-13].

3.1. Analysis of landscape pattern changes in category scale

The temporal and spatial landscape change of six landscape types in different periods are analyzed. The eigenvalue of landscape types indices are shown in Table 4.

Table 4. The eigenvalue of landscape pattern in Yanzhou city

Landscape	Year	Building area	Cropland	Garden land	Water	Woodland	Bare land
Total Area (TA)	1998	16403.47	45657.54	1668.09	1563.39	1019.11	646.97
	2002	14937.27	42001.96	2432.27	1998.50	3602.81	1985.33
Number of Patches (NP)	1998	10147	3326	5872	2331	2536	1365
	2002	9043	4680	11077	6357	7766	2291
Patch Density (PD)	1998	10.1183	3.3166	5.8554	2.3244	2.5288	1.3611
	2002	9.0174	4.6668	11.0457	6.3390	7.7440	2.2845
Edge Density (ED)	1998	68.0133	79.7178	15.3377	8.0632	6.5365	4.1987
	2002	61.0116	77.2524	15.8552	15.85526	22.6625	6.6283
Landscape Shape Index (LSI)	1998	133.1157	93.5100	90.8687	50.1272	56.3725	41.2682
	2002	127.1931	92.2151	126.8617	88.8376	103.5688	52.7692
Largest Patch Index (LPI)	1998	3.6633	33.7821	0.0522	0.3292	0.0153	0.0552
	2002	5.4809	29.0693	0.0275	0.0636	0.0518	0.0520
Mean of Patch Area Distribution (AREA_MN)	1998	1.6166	13.7275	0.3037	0.6960	0.3331	0.4740
	2002	1.5982	9.4193	0.2200	0.3144	0.3867	0.4301
Mean of Fractal Index Distribution (FRAC_MN)	1998	1.2804	1.2001	1.1522	1.1709	1.1321	1.1591
	2002	1.2694	1.2193	1.1503	1.1374	1.1779	1.1557
Mean of Shape Index Distribution (SHAPE_MN)	1998	1.0456	1.0336	1.0341	1.0356	1.0336	1.0357
	2002	1.0448	1.0383	1.0353	1.0326	1.0399	1.0362

(1) Cropland

Cropland is the dominant landscape, which covers the largest area. The area of cropland is decreased from 45657.54 hm^2 in 1998 to 42001.96 hm^2 in 2002, but the number of patches increases from 3326 to 4680 resulting in patch density from 3.3166 to 4.6668. Landscape shape index and the average fragmentation index increase due to the cropland transformation and fregmentation. The cropland mainly distributes the northeast and southwest of Yanzhou from Fig.2. The cropland of surrounding city and towns in the east in 1998 has transformed into building land in 2002.

(2) Woodland

The woodland area in 2002 is largely more than the area of 1998 in Yanzhou. Correspondingly, the patch numbers and patch density are almost two times as much as before. The edge density and landscape shape index also have a great increase, but the greatest patch index decrease. These indices show that woodland greening has been paid more attention to make the area of the natural woodland dispersed and the area of the artificial woodland greatly increased.

(3) Garden land

The garden land increases 764.18 hm^2 from 1998 to 2002. The number of patches, landscape shape index and patch density increase a lot, and the greatest patch index decreases. These indices indicate that lots of garden land with large area decrease and the scattered garden land increase. The shape of garden land presents diversity because of the human transformation activities.

(4) Building land

The building area has gone down in the past four years. The number of patches, patch density, edge density and landscape shape index decrease and the largest patch index increases, which show that the building area has a trend of conglomeration. The mean of fractal index distribution decreases to imply that the connection and integrityof building area is strengthened and the urban is well developed due to the transformation of natural environment.

(5) Water

Although water increased a little, the number of patches increase a lot, which result in the increase of patch density and landscape shape index. However, the largest patch index and mean of patch area distribution decrease. This phenomenon engenders maybe due to the new subsidence area, environment, weather and other manual activity.

(6) Bare Land

Bare land increases almost two times from 1998 to 2002. While the number of patches, patch density, edge density, and landscape shape index increase a lot, but the mean of fractal index distribution, largest patch index and mean of shape index distribution keep invariant. These mean that the number of patches increasing. However, the area of single patch is not expanded. The distribution points of bare land increase maybe resulting from the soil erosion or other reasons.

3.2. Analysis of landscape pattern changes in landscape scale

Due to the more and more effect of human transformation on urban development, the number of patches increase 15 637 from 1998 to 2002 and the mean of patch area distribution has a trend of decrease to make the patch density rapidly increased. With the increase of the number of patches, the mean of shape index distribution and the mean of fractal index decrease and the patch shape is simplified. The increase of diversity index indicates that the effect elements of landscape pattern increase and landscape structure is complicated.

Table 5. Comparison of Yanzhou city landscape dynamics from 1998 to 2002

Landscape Index	1998	2002
Totel area(TA) (hm^2)	66958.57	66958.57
Number of Patches (NP)	25581	41218
Patch Density (PD)	25.5086	41.1014
Edge Density (ED)	91.7253	105.0060
Landscape Shape Index (LSI)	73.5987	84.1095
Largest Patch Index (LPI)	33.7821	29.0693
Mean of Patch Area Distribution (AREA_MN)	3.9202	2.4330
Mean of Shape Index Distribution (SHAPE_MN)	1.2095	1.1879
Mean of Fractal Index (FRAC_MN)	1.0388	1.0382
Degrees Rich Plaque (PR)	6	6
Landscape Dominance (D)	0.5602	0.4664
Shannon Diversity Index (SHDI)	1.2316	1.3254

The type of ecological environment in Yanzhou is in good state (Table 5). First, most landscapes made of cropland, woodland and garden land ensure the landscape pattern. Second, the fragmentation of building area reduces and the integrity strengthens. Finally, the landscape has the rich diversity and the low dominance. The proportion of the landscape types has no remarkable diference and the landscape types commonly develop.

4. Conclusions

1) The best band combinations are selected to interpret the images based on the correlation coefficient of bands

and Optimum Index Factor(OIF). Then the SVM claasifier is used to classify the images and its classification precision is satisfied the analysis requirement of urban landscape pattern change.

2) In the process of urban development and mine development, the type of ecological environment in Yanzhou is in good state. Most landscapes made of cropland, woodland and garden land ensure the landscape pattern. The fragmentation of building area reduces and its integrity strengthens.

3) The cropland and building area of Yanzhou city reduce from 1998 to 2002, woodland and garden land increase. But the bare land should be paid more attention because of its large increase.

4) The landscape has a rich diversity and a low dominance and all landscapes commonly develop, which means that the balanceable development of protecting the objects style is paid more attention to and the ecological environment type keeps in good condition on the whole.

Acknowledgements

This research has been supported by the Science Foundation of Postdoctors in China.

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